

CLAIMS

What is claimed is:

1 1. A hardware-adaptable data visualization tool for use in
2 visualizing data from a data source, comprising:
3 a) a data source module, responsive to data source input files
4 indicating information about a geometry to be visualized,
5 for providing as a stream of data to be interpreted a
6 numerical data set representing aspects of the data; and
7 b) a viewer module, for providing the data source input files,
8 responsive to the numerical data set for providing a view
9 of the numerical data set helpful to a user in interpreting
10 the numerical data set;

11 wherein the viewer module in turn comprises a plurality of
12 viewer component modules, and wherein the source module and the
13 viewer component modules are compiled and linked together into
14 one or more executable files depending on factors including at
15 least either the performance capabilities of a predetermined
16 target host or hosts or the desired utility of the executable
17 files, the component modules having programming interfaces that
18 are substantially independent of the predetermined target host
19 or hosts, whereby different visualization tools are able to be
20 provided all from the same data source module and viewer
21 component modules, the different visualization tools being
22 tailored to different performance capabilities of different
23 target hosts.

1 2. A hardware-adaptable data visualization tool as claimed in
2 claim 1, wherein the viewer component modules comprise:
3 a) a geometry manager, responsive to geometry information
4 describing the boundaries of a geometry corresponding to a

5 region being viewed and responsive to changes in the
6 geometry information and associated display
7 characteristics, for providing a representation of the
8 boundaries of the region being viewed, and for providing
9 the data source input files including information about the
10 geometry;

11 b) an interface module, serving as the means by which a user
12 of the data visualization tool requests views or requests
13 to view objects, responsive to user tool controls and
14 inputs, for providing changes to the geometry and
15 associated display characteristics, for providing display
16 characteristics associated with graphic representations of
17 visualization objects, for providing flight plans
18 indicating information for providing a view of the
19 numerical data set, and also responsive to summary data,
20 and further for providing graphics output of the summary
21 data;

22 c) an automation/scripting module, for maintaining flight
23 plans or other standardized instructions for viewing the
24 numerical data set, responsive to the flight plans, for
25 providing changes to display characteristics associated
26 with the flight plans;

27 d) a visualization object client/graphics module, for
28 retrieving, storing, and displaying dynamic visualization
29 objects that represent information in the numerical data
30 set, responsive to changes to display characteristics,
31 responsive to and for providing summary numerical data, and
32 responsive to visualization data, and for providing
33 graphics representations of visualization objects;

34 e) a visualization object server, for generating graphical
35 objects, responsive then to data for generating graphical
36 objects, for providing the generated graphical objects;

- 37 f) an auxiliary calculation module set, for translating the
38 numerical data set after standard formatting into data for
39 visualization, for providing the data for visualization;
40 and
41 g) a query library module, for converting different data
42 source program data structures into a standard application
43 programming interface and so allowing visualization of data
44 from data source programs that output data in different
45 formats, responsive to the numerical data set, for
46 providing the numerical data set according to standard
47 formatting;

48 wherein the data source module is selected from the group
49 consisting of calculatory data source modules and non-
50 calculatory data source modules.

3. A hardware-adaptable data visualization tool as claimed in
claim 2, wherein the data source module is a computational fluid
dynamics (CFD) module.

4. A hardware-adaptable data visualization tool as claimed in
claim 2, wherein all of the viewer component modules are compiled
and linked together into a single executable file and the data
source module is compiled into a separate executable file,
thereby providing a data visualization tool in which computing
equipment most suitable for computation can be used as a host of
the data source module, and computing equipment most suitable for
providing a view helpful in interpreting the data stream provided
by the data source module can be used as a host of the viewer.

5. A hardware-adaptable data visualization tool as claimed in
claim 2, wherein the data source module is linked together into a
single executable file, the query module, the auxiliary

4 calculational module set, and the visualization object server
5 module are compiled and linked together into a single executable
6 file, and the other component modules of the viewer module are
7 compiled and linked together into a single executable file,
8 thereby a data visualization tool that is distributed across up
9 to three different target hosts, communicating via a network
10 and/or a file system.

1 6. A hardware-adaptable data visualization tool as claimed in
2 claim 2, wherein the data source module, the auxiliary
3 calculational module set, such as the tracking module, and the
4 query module are compiled and linked together into one executable
5 file, thereby making possible the use of the tracking module to
6 generate information on spray trajectories or other similar
7 information generated by an other auxiliary calculational module
8 and used as a basis for source term inputs to the data source
9 module during execution, and wherein the remaining modules,
10 however compiled and linked, form the viewer.

1 7. A hardware-adaptable data visualization tool as claimed in
2 claim 2, wherein all of the viewer component modules and the data
3 source module are compiled and linked together into a single
4 executable file, thereby providing a viewer with a capability of
5 examining intermediate results of the data source module as it
6 performs a calculation and steering the calculation of the data
7 source module.

1 8. A hardware-adaptable data visualization tool as claimed in
2 claim 2, wherein the data source module, the query library
3 module, the auxiliary calculational module set, and the
4 visualization object server are all compiled and linked together
5 into one executable file, and the other modules, the principal

viewer modules, are all compiled and linked together into a second executable file, and wherein the viewer is connected to the data source module via a network link, and so is able to examine intermediate results of the data source module as it performs a calculation and steer the calculation as the data source module is performing the calculation.

9. A hardware-adaptable data visualization tool as claimed in claim 1, wherein the tool is used for the analysis and engineering design of a fluid dynamic system, wherein the data for visualization provided by the tracking module is particle trajectory data, and further wherein:

- a) the data source module is a computational fluid dynamics (CFD) module, responsive to data on the geometry of the fluid dynamic system, and provides, as a stream of data to be interpreted, a numerical data set representing flow; and
- b) the viewer module is responsive to the numerical data set representing flow, and provides the data on the geometry of the fluid dynamic system, and also provides a view of the numerical data set representing flow in an environment, such as a fully immersive environment, that helps a user interpret the numerical data set.

10. A hardware-adaptable data visualization tool as claimed in claim 1, wherein the tool is used for the analysis and engineering design of a fluid dynamic system in which a reacting flow occurs, and further wherein:

- a) the data source module is a computational fluid dynamics (CFD) module, responsive to data on the geometry of the fluid dynamic system, and further responsive to data on sources of reacting species being added to the reacting flow, and provides, as a stream of data to be interpreted,

10 a numerical data set representing flow and other
11 characteristics of the reacting flow; and

- 12 b) the viewer module is responsive to the numerical data set
13 representing flow and other characteristics of the reacting
14 flow, and provides the data on the geometry of the fluid
15 dynamic system, and also provides a view of the numerical
16 data set representing flow and other characteristics of the
17 reacting flow in an environment, such as a fully immersive
18 environment, that helps a user interpret the numerical data
19 set.

10 11. A hardware-adaptable data visualization tool as claimed in
11 claim 1, wherein the tool is for use in designing targeted in-
12 furnace injection systems, such as pollution control systems, for
13 controlling a combustion process, the special features for
14 introducing into the combustion process species that react with
15 the combustion products, and further wherein:
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- 17 a) the data source module is a computational fluid dynamics
18 (CFD) module, responsive to data on the geometry of the
19 combustion system including the special features, and
20 further responsive to data on sources of the reacting
21 species being added to the combustion process, and
provides, as a stream of data to be interpreted, a
numerical data set representing flow and other
characteristics of the combustion process; and
b) the viewer module is responsive to the numerical data set
representing flow and other characteristics of the
combustion process, and provides the data on the geometry
of the combustion system including the special features,
and also provides a view of the numerical data set
representing flow and other characteristics of the
combustion process in an environment, such as a fully

22 immersive environment, that helps a user interpret the
23 numerical data set.

1 12. A hardware-adaptable data visualization tool as claimed in
2 claim 1, wherein the data visualization tool comprises two or
3 more different viewer modules, wherein one viewer module is
4 hosted by a first computer, another viewer module is hosted by a
5 second computer, and so on, and wherein the viewer modules use
6 the same model data.

1 13. A hardware-adaptable data visualization tool as claimed in
2 claim 1, wherein multiple synchronized dialog boxes are used to
3 prevent data corruption.

1 14. A hardware-adaptable data visualization tool as claimed in
2 claim 1, wherein separate control dialog boxes and visualization
3 windows are provided.

1 15. A hardware-adaptable data visualization tool as claimed in
2 claim 2, wherein a strong scripting language is used to provide
3 input to the automation and scripting module for directing real-
4 time visualization.

1 16. A hardware-adaptable data visualization tool as claimed in
2 claim 1, wherein a script file is used to generate a complex
3 visualization picture.

1 17. A hardware-adaptable data visualization tool as claimed in
2 claim 1, wherein object structures are provided that can use the
3 same graphics libraries with more than one VR base library,
4 including a CAVELib based application or a VR Juggler based
5 application.

1 18. A hardware-adaptable data visualization tool as claimed in
2 claim 1, wherein the viewer places multiple graphical
3 representations of particles on a single streamline, allowing the
4 streamline to visually represent more particles than are
5 calculated.

1 19. A hardware-adaptable data visualization tool as claimed in
2 claim 1, wherein streamlines are colored by time of life.

1 20. A hardware-adaptable data visualization tool as claimed in
2 claim 1, wherein a programming interface is provided allowing a
3 user to code a color map using one or another function $f(s)$ for
4 mapping a scalar value s to a desired color.

1 21. A hardware-adaptable data visualization tool as claimed in
2 claim 1, wherein one code section is used to visualize all
3 different types of graphical tracking objects, such as
4 streamlines, injectors, and massed injectors.

1 22. A hardware-adaptable data visualization tool as claimed in
2 claim 2, wherein each of the modules are implemented according to
3 an object-oriented design so as to allow the viewer to interpret
4 any type of data.

1 23. A hardware-adaptable data visualization tool as claimed in
2 claim 1, wherein each of the modules are implemented according to
3 an object-oriented design so as to allow the application to
4 interpret different types of cells in a single data source output
5 file.

1 24. A hardware-adaptable data visualization tool as claimed in

claim 1, wherein each of the modules are implemented according to an object-oriented design so as to allow pluggable readers for data sets provided by the data source program.

25. A hardware-adaptable data visualization tool as claimed in claim 1, wherein injector characteristics are definable via a plug-in.

26. A hardware-adaptable data visualization tool as claimed in claim 1, wherein particle plug-ins are used to enable a user to develop different particle characteristics.

27. A hardware-adaptable data visualization tool as claimed in claim 1, wherein contour planes are constructed by sampling points on a regular two-dimensional grid, thereby providing contours that are grid-independent.

28. A hardware-adaptable data visualization tool as claimed in claim 1, wherein the viewer component modules comprise:

- a) a data visualization module, responsive to geometry information describing the boundaries of a geometry corresponding to a region being viewed and responsive to changes in the geometry information and associated display characteristics, for providing a representation of the boundaries of the region being viewed, and for providing the data source input files including information about the geometry, and also for retrieving, storing, and displaying dynamic visualization objects that represent information in the numerical data set and so responsive to changes to display characteristics, also responsive to and for providing summary numerical data, and responsive to

15 visualization data, and for providing graphics
16 representations of visualization objects;
17 b) an interface system module, an interface module, serving as
18 the means by which a user of the data visualization tool
19 requests views or requests to view objects, responsive to
20 user tool controls and inputs, for providing changes to the
21 geometry and associated display characteristics, for
22 providing display characteristics associated with graphic
23 representations of visualization objects, and also
24 responsive to summary data, and further for providing
25 graphics output of the summary data, also for maintaining
26 flight plans or other standardized instructions for viewing
27 the numerical data set, for providing changes to display
28 characteristics associated with the flight plans;
29 c) a data interpretation module, for generating graphical
30 objects, responsive to data for generating graphical
31 objects, for providing the generated graphical objects, and
32 also for translating the numerical data set after standard
33 formatting into data for visualization, for providing the
34 data for visualization; and
35 d) a data translation module, for converting different data
36 source program data structures into a standard application
37 programming interface and so allowing visualization of data
38 from data source programs that output data in different
39 formats, responsive to the numerical data set, for
40 providing the numerical data set according to standard
41 formatting;
42 wherein the data source module is selected from the group
43 consisting of calculatory data source modules and non-
44 calculatory data source modules.
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